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**Mixing Effects on the Precipitation and Cross Flow Filtration of a Hanford Simulated
Precipitated Radioactive Waste**

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**Filtration of a Hanford Site Tank 241-AN-102 Waste Sample
with Alternate Sr/TRU Precipitation Conditions at Bench and Pilot Scales**

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Summary

As part of the River Protection Project at Hanford, Washington, Bechtel National, Inc. has been contracted by the United States Department of Energy to design a Waste Treatment and Immobilization Plant to stabilize liquid radioactive waste. Because of its experience with radioactive waste stabilization, the Savannah River Technology Center of the Westinghouse Savannah River Company is working with Bechtel National and Washington Group International, to help design and test certain parts of the Waste Treatment Plant. One part of the process is the separation of radioactive isotopes from the liquid waste by a precipitation reaction and cross-flow ultrafiltration. To better understand those combined processes an experiment was performed using a simulated radioactive waste, made to prototypically represent the chemical and physical characteristics of a Hanford waste in tank 241-AN-102 and precipitated under prototypic conditions. The resultant slurry was then filtered using a cross-flow filter prototypic in porosity, length, and diameter to the plant design.

An important aspect of filtration for waste treatment is the rate at which permeate is produced. There are many factors that affect filtration rate and one of the most difficult to obtain is the effect of particles in the waste streams. The Waste Treatment Plant will filter many waste streams, with varying concentrations and types of dissolved and undissolved solids. An added complication is the need to precipitate organic complexants so they can be efficiently separated from the supernatant. Depending on how precipitation is performed, the newly created solids will add to the complicating factors that determine permeate flux rate. To investigate the effect of precipitated solids on filter flux a pilot-scale test was performed and two different mixing mechanisms were used for the precipitation reaction. A standard impeller-type mixer, which created a homogeneous mixture, and a pulse jet mixer, which created a "less than" homogeneous precipitation environment. Pulse jet mixers are included in the design of the Waste Treatment Plant because they have no moving parts, which is advantageous for radioactive operations as no maintenance is required. A pulse jet mixer uses alternate pulses of pressurized air and vacuum to mix tank contents. This pulse jet mixer was not expected to establish a homogeneous mixture throughout the test tank, therefore, it was important to know its effect on filtration after a waste is precipitated.

This paper discusses the experimental results of cross-flow filter flux after a simulated waste is precipitated under each of the two mixing methods. The main conclusion reached is that while

the “less than well mixed” jet-pulsed waste gave a lower average filter flux it may still be sufficiently large enough to meet plant requirements.

Introduction

The Savannah River Technology Center (SRTC) has conducted pilot scale precipitation and cross-flow ultrafiltration tests to support the design of the DOE River Protection Project Waste Treatment and Immobilization Plant (WTP) to be built at Hanford, Washington. The pilot scale precipitation testing using a non-radioactive simulant of Hanford Tank 241-AN-102 (AN-102) was performed to demonstrate operability and determine filtration throughput for a Sr/TRU precipitated waste. The precipitation reaction was done under two different mixing environments with strontium nitrate and sodium permanganate as reagents (Williams 2004). The first test used a standard mechanical agitator and the batch size was 880 liters, while the vessel was a 938-liter polypropylene baffled tank. The second test used a pulse jet mixer (PJM) and the batch size was 572 liters, while the vessel was another 938-liter polypropylene tank without the baffles. Baffles help with mixing homogeneity in impeller-agitated tanks by inhibited solid body motion, but for PJM, where bulk mixing is slow and baffles hinder mixing; therefore, they are not used. The batch size in the pulse mixed tank was limited by the need to scale the pulse jet liquid volume and tank volume to the full size WTP system.

After precipitation for both tests, the slurry was transferred to the pilot-scale cross-flow filter (Duignan 2003). The cross-flow filter unit was manufactured by Mott Metallurgical Corporation to RPP-WTP specifications. The unit was comprised of 7 filter tubes with each tube having an inside diameter of 0.5 inches, a 90-inch porous length made of stainless steel, and a nominal pore-size rating of 0.1 micron. The cross-flow pilot test rig was designed to have a maximum axial velocity through the filter tubes of 15 ft/s (4.6 m/s) and a maximum transmembrane pressure (TMP) of 60 psid (387 kPa). However, for these tests these filter parameters were held constant at 12 ft/s (3.7m/s) and 40 psid (276 kPa), respectively.

The simulant tested was modeled after the waste in Hanford Tank AN-102. This waste is classified by RPP-WTP as “Envelope C” because it contains significant amounts of organic chelating agents. Envelope C wastes will undergo isotopic dilution with strontium nitrate to reduce the soluble ^{90}Sr concentration, and sodium permanganate precipitation to remove selected transuranic (TRU) species. These two treatments are referred to as “Sr/TRU precipitation.” The goal of the filtration in the WTP is to increase the undissolved solids content of the precipitated waste to at least 15 wt%.

Simulant and Sr/TRU Precipitation

An AN-102 simulant formulation developed by SRTC was used for this work (Eibling 2002). This simulant included both a supernatant fraction and an entrained solids fraction. The solids fraction of the simulant comprised only 0.1 weight percent of the total mass. The base formulation is shown in Table 1.

The Sr/TRU precipitation was performed by the following steps: first, enough NaOH was added to the simulant at 6.0M sodium so that the total hydroxide concentration was between 1.0 to 1.2 M, then $\text{Sr}(\text{NO}_3)_2$ was added, while the mixed simulant was maintained at 50°C, to give a

final Sr concentration of 0.075M, and finally, NaMnO_4 , at 50°C, was added to increase the Mn concentration to 0.05M.

Table 1. Typical Simulant Composition

Species	mg/L	Species	mg/L	Species	mg/L
Al	9500	W	137	NO_2^-	54500
B	38.3	Zn	4.45	NO_3^-	137000
Ba	0.45	Zr	8.1	Cl^-	3700
Ca	407	K	2860	F^-	921
Cd	36.2	La	24.3	PO_4^{-3}	1970
Ce	28.8	Mg	1.01	SO_4^{-2}	10400
Co	1.44	Mn	16.6	formate	7350
Cr	156	Mo	30.7	oxalate	343
Cu	7.2	Na	137000		M
Fe	30.6	Nd	40.3	free OH^-	0.216
S	3380	Ni	265	total base	1.66
Sr	2.94	P	696		
Si	40.2	Pb	63.4	SpG	1.32

Experimental Equipment

Mechanical Agitated Mixing

Figure 1 is a schematic of the Mechanically Agitated Pilot Scale Precipitation Test Rig. The test rig was fabricated utilizing PVC and CPVC plastic pipe, with tubing made of stainless steel and polypropylene. A vertically mounted Lightnin agitator with 12.8-inch diameter A-310 style impeller provided vigorous uniform mixing of the simulant without splashing. Besides the agitator, the 938-liter polypropylene precipitation tank had baffles to enhance mixing. The temperature of the simulant batch was controlled by pumping the batch through a large recirculation loop containing an electric heater and a chilled water heat exchanger. The large recirculation loop had a pump rated for slurry service installed with a speed controller to vary the flow as necessary for mixing or precipitation sampling. The large loop was also used to rapidly cool the precipitated slurry to 25°C before its transfer to the cross-flow filter test rig. Dilution water and chemicals were manually added through an access port in the tank cover. The two precipitation reagents each had a dedicated tank, recirculation pump, recirculation piping, and flow meter. The sodium permanganate tank was opaque, stainless steel, as the reagent is sensitive to light and is a strong oxidizer. The tank for the other reagent, strontium nitrate, was polypropylene. Typically, the reagents were mixed in the tanks by recirculating the solution at the desired flow rate, then the aqueous solution was directed to the precipitation tank for addition at a prescribed rate. The strontium nitrate was added first and allowed to mix throughout the precipitate tank before adding the sodium permanganate.

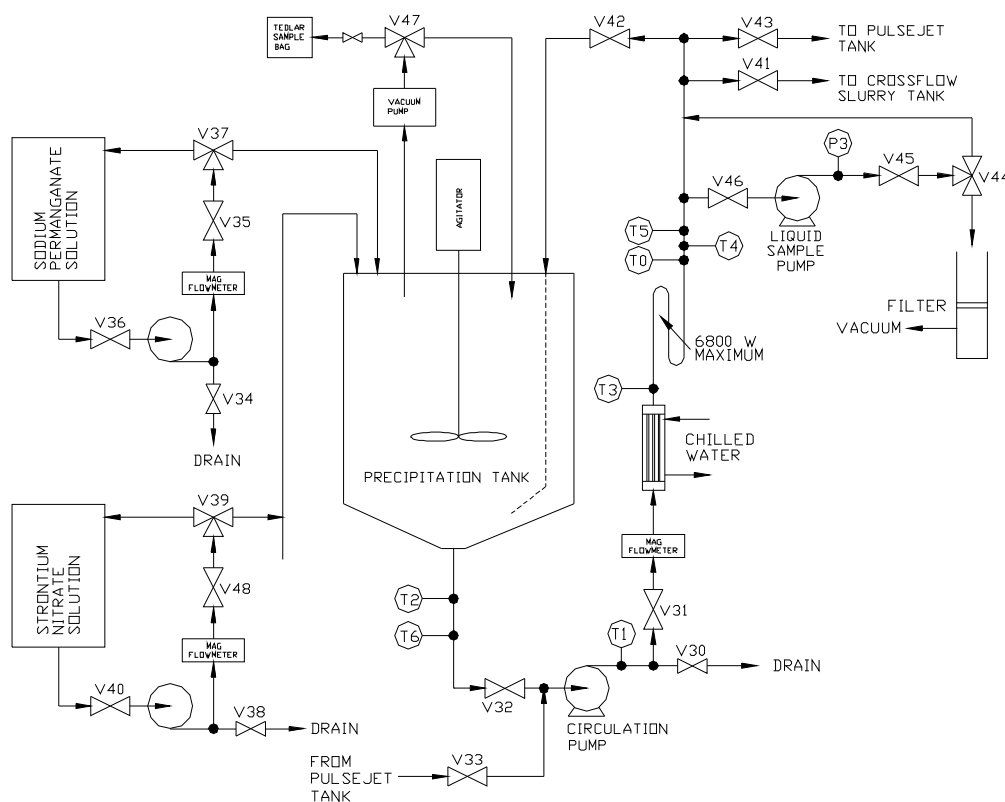


Figure 1. Mechanically Agitated Pilot-Scale Precipitation Test Rig

A sample of the mechanically agitated precipitation tank contents could be drawn off with a pump connected to the main recirculation loop. The take-off from the recirculation line was a thin-wall, small-diameter tube about a foot long installed concentrically inside the recirculation loop and pointing into the flow. The tube and recirculation pipe were sized to have identical flow velocities at a recirculation flow rate of 36 lpm (9.6 gpm) and a sample rate of one liter every 20 seconds. Typically, flow was established through the sample pump and returned to the recirculation loop to ensure the line was full and flushed with fresh material. The flow was then quickly directed to the collection container, then redirected back to the recirculation loop when approximately one liter of sample was collected. Trial runs were used to preset throttle valve V45 to deliver one liter in 20 seconds. Some slurry samples were submitted directly for certain analysis, others were dead-end filtered to separate the solids from the liquid portion for a separate analysis.

Jet Pulse Mixing

The pulse jet mixer (PJM) precipitation test rig is shown in Figure 2. The JPM used a pulse of pressurized air to force liquid rapidly through a nozzle at the bottom of the pulse tube, then the tube was refilled with tank liquid due to the difference in hydrostatic pressure inside and outside the partially emptied tube. A vacuum was applied to speed up the refill of the tube, or to raise the level inside the tube above the tank level to provide a larger pulsed volume. The discharge and refill cycle was repeated at a prescribed frequency to mix the tank contents. The liquid level in the PJM tube was controlled and measured by a capacitance probe.

The PJM operation was computer controlled. A 3-way solenoid valve was controlled to set the air supply until the air pressure applied at the top of the pulse tube lowered the liquid level in the tube to a set level. The computer then switched the valve to the vacuum/vent line and opened the vacuum solenoid until the liquid rose to the set level. The vacuum was then shut and the PJM vented, until the desired cycle time was reached to begin the next cycle. When the 3-way valve was switched to apply vacuum, the liquid level in the pulse tube did not immediately stop dropping. The air inside the pulse tube continued to expand, discharging liquid until air being removed by the vacuum pump lowered the pressure below that of the outside liquid. Similarly, the liquid level did not stop rising immediately when the vacuum was shut off and the system vented. If the total cycle time was too short, the level in the pulse tube could not reach equilibrium with the outside tank level.

The PJM system was made to have a one-to-one liquid height-to-tank diameter ratio after reagent additions to match the ratio in the WTP design, which also required a pulse of injected liquid of approximately 6% of the tank-liquid volume. Moreover, RPP-WTP specified a PJM inside diameter of 10 inches and a nozzle diameter of 2 inches. These requirements fixed the dimensions of the batch size at 572 liters.

Several of the systems used for the mechanical agitated test setup were also used by the PJM, like the reagent tanks and the large recirculation loop, compare Figs. 1 with 2. However, a separate smaller recirculation loop with its own heater was provided for the PJM to maintain the temperature of the tank contents at 50°C during the precipitation.

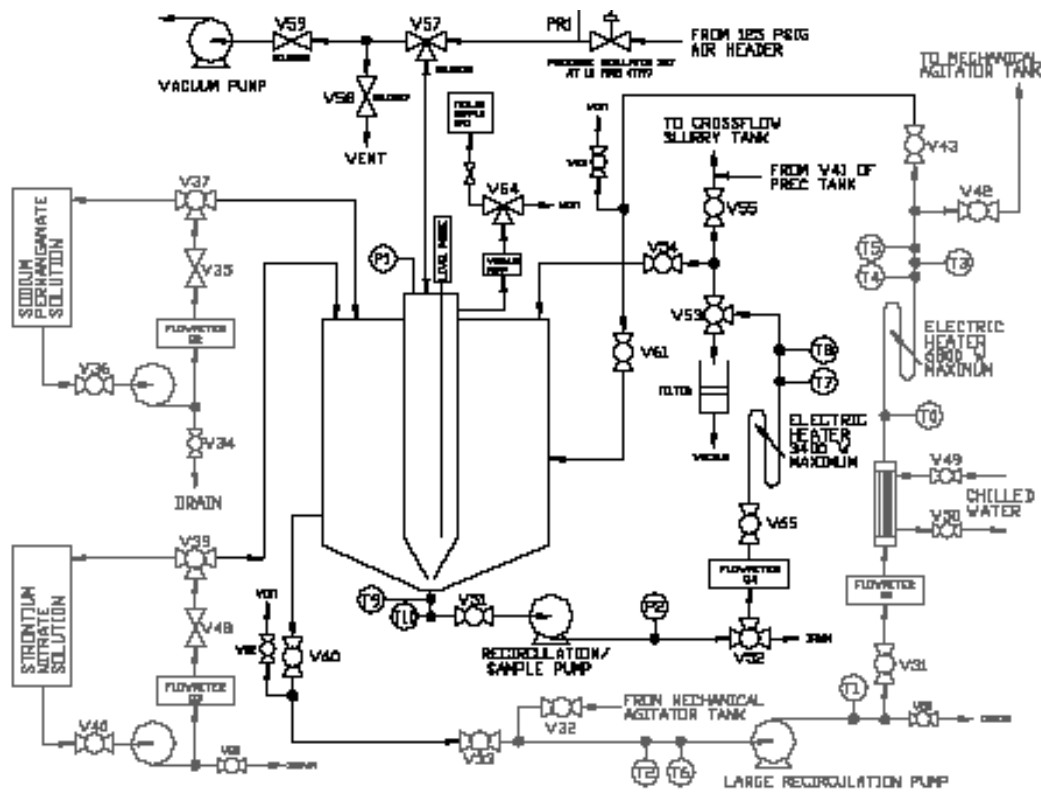


Figure 2. Pulse Jet Mixed Pilot-Scale Precipitation Test Rig

Cross-flow Ultrafilter

Figure 3 is the Pilot-Scale Crossflow Test Rig (Duignan 2003). The simulant was circulated by two 10-hp, centrifugal pumps, in series, and the pump heat was removed with an in-line heat exchanger. These slurry pumps were manually controlled by variable frequency drives, providing excellent control of the flow. The filter and piping was made of 300 series stainless steel. The test rig had two basic flow loops:

- Slurry loop, which contains the two centrifugal pumps, heat exchanger, flowmeter, pressure and temperature measurements, throttle valve, and cross-flow filter. This loop serves as the primary flow path for circulating slurries and has an internal volume of approximately 20 liters, excluding the slurry reservoir.
- Permeate loop, which begins at the filter housing, allows the separated permeate liquid to flow up through the backpulse system before returning to the top of the slurry loop to close the circuit. This loop has an internal volume of approximately six liters. Note that this loop has a three-way valve that can be positioned to draw off the permeate to a collection tank rather than returning it to the slurry loop. This option is used during dewatering to concentrate the slurry.

Two other flow circuits that are subsections of the other loops are the backpulse and the bypass loops:

- The backpulse loop is part of the permeate loop. It functions to reverse the flow of permeate back through the filter elements in order to knock off built-up slurry cake on the inside diameter of the porous tubes. The system used a flow-through pulsepot that can be isolated and pressurized with air just prior to backpulsing. When the pressurized pot is valved back to the cross-flow filter housing, there is an initial high pressure pulse with a rapidly increasing flow. As the air in the pot expands and drops in pressure, the flow rate peaks then gradually drops off to zero. This system is prototypic of the full-scale RPP-WTP equipment. A detailed discussion of the design and operational experience with this backpulse system can be found in Duignan (2003).
- The bypass loop is part of the slurry loop and routes part of the flow through valve V6 back to the reservoir. This loop is used to better control the slurry flow during slurry pump startup, improve mixing, and ensure the slurry remains well-mixed when the flow through the filter needs to be stopped.

The slurry reservoir is a 110-liter plastic tank that receives feed from the precipitation tank. When necessary, direct addition to the slurry reservoir was made via the funnel attached to the V4 valve. The precipitated waste simulant in the filter slurry reservoir was kept well mixed.

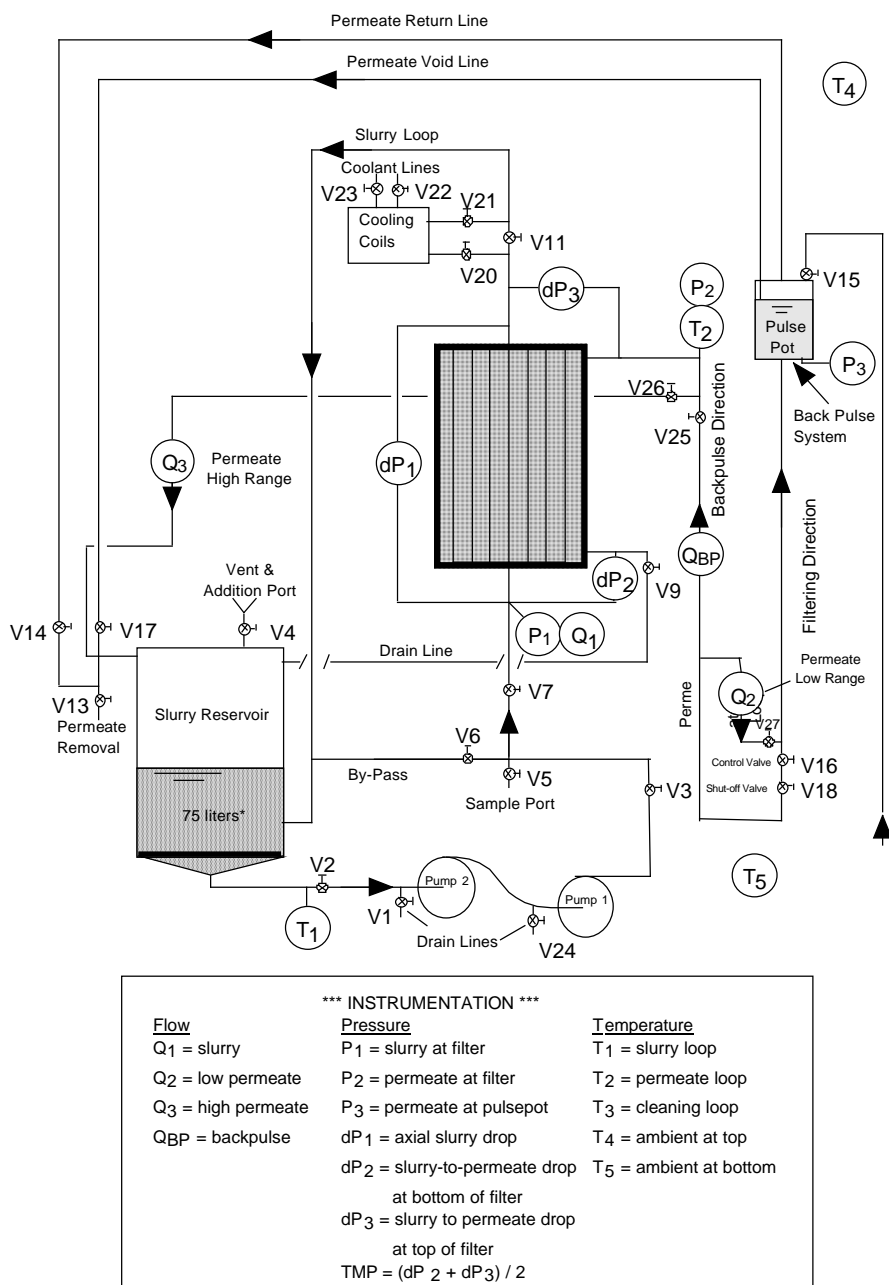


Figure 3. Schematic of the Pilot-Scale Cross Flow Ultrafiltration Test Facility

The principal part of the filter test rig is the filter unit. Figure 4 (a) shows a picture of the filter elements outside of their housing and Fig. 4 (b) illustrates the flow of slurry through a tube and exiting flows of concentrated slurry and separated permeate. An important feature of the filter is the pore size to separate liquid from a slurry stream. For this work the pore size was nominally 0.1 micron. However, as seen in Fig. 4 (b) a cake of solids builds up on the porous surface and it is that cake which actually does the filtering. The turbulent flow of slurry helps to keep the cake thickness to a minimum but its ability to filter will depend on the make-up of the slurry and the nature of the cake. These differences in cake structure are what will control the filtering process and the overall rate of separation. The precipitation of solids from wastes will

create unknown particle sizes and consistencies, therefore the current testing was done to evaluate filter fluxes in the presence of these unknown and complex parameters.

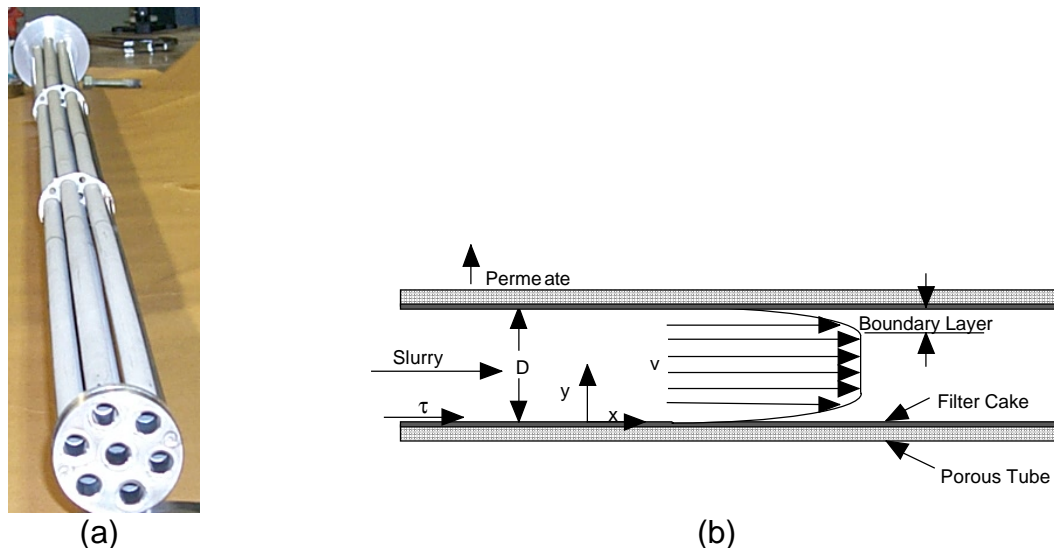


Figure 4. (a) Cross-flow filter elements, and (b) schematic of flow through a tube

Precipitation Testing

The simulated supernatant was loaded into the clean precipitation tank and the agitator was turned on. To the mixing liquid the small amount of entrained solids was added. The recirculation pump flow was adjusted to the proper rate and a sample of the simulant was collected.

To begin the precipitation process enough caustic was added to attain a 1.0 M OH⁻ concentration. Then the temperature was brought to 50°C and another sample was drawn. Once the mixture reached the target temperature the mixing continued for 60 minutes before adding the strontium nitrate. The strontium nitrate reagent was then directed to the precipitation tank at the necessary flowrate for approximately 45 minutes, to attain the prescribed volume. While precipitation was ongoing the mixing continued for 15 minutes before the next sample was drawn.

The next reagent, sodium permanganate, was added to the precipitating mixture at approximately 30 minutes from the time that previous reagent addition ended. This addition was transferred at a prescribed rate for approximately 25 minutes, until the needed volume was incorporated. While being held at 50°C, the precipitation was allowed to continue for four more hours before filtration began. During that period samples were taken after 7.5, 15, 30, 60, 120, 160, and 240 minutes to capture the dynamics of precipitation. For the mechanical agitated test, filtering began immediately after the 4 hours by transferring a portion of the precipitated mixture to the cross-flow filter test rig. As dewatering began the simulant was cooled to 25°C within a few minutes by the heat exchanger in the filter loop. Subsequently, simulant in the filter test rig was continually replenished with more fresh feed in batches of approximately 50 liters, until the precipitation tank was emptied. At this point the final undissolved solids concentration was targeted to reach 20 wt%. For the PJM test the process

was similar except there was a cooling time of 18 hours from the end of the 4-hour precipitation period. After the 18-hour period the simulant temperature was around 30°C, therefore, the filter loop did not have to provide much cooling to attain 25°C.

Mixing Environments

Standard Agitator

The agitator was a model A310 Lightnin impeller with a 12.8-inch diameter. It was rotated at 508 rpm giving a tip speed of 26.6 ft/s and an energy displacement of 4.3 hp / 1000 gallons. The rule-of-thumb for this energy level is that it will create a well-mixed environment. Using baffles and visual observation reinforced this assumption.

Jet Pulse Mixer

Less than well mixed conditions were assumed for the single jet PJM used in this test, but whether or not they would affect filtration was not known. It was important to replicate the mixing that RPP-WTP expected in its precipitation tank. The plant design at that time required pulsing 6% of the tank volume every 77 seconds, using a 19-second duration pressure pulse. However, RPP-WTP indicated that the tank surface velocity should be 1 ft/s or greater in the belief this would indicate good mixing. Experimentation in the precipitation tank showed that surface motion of about 1 ft/sec could be obtained with a pulse of 6% of the tank volume if a 1.6 second pressure pulse duration were used. Therefore, the total cycle time was kept at 77 seconds to match the plant design, but the 6% liquid volume was pulsed for 1.6 seconds to attain the higher liquid surface motion.

During shakedown with water and unreacted simulant, the PJM control system was found to be quite stable and provide repeatable pulses. However, once precipitation started the controls had to be continually adjusted to maintain the desired pulse as the precipitation reaction progressed. Apparently the properties of the slurry changed enough to affect the pulse significantly. Without careful adjustments air would have blown out the nozzle, which had to be avoided.

The mixing during the reagent addition visually seemed to be better than generally expected. After the strontium nitrate was added to the top of the liquid surface the mixture had the typical yellowish color due to the strontium carbonate solids formed. Once the sodium permanganate was added, the liquid at the surface became a dark brown/purple, but the recycle stream, pumped from the bottom of the tank, was still yellow in color. About 20 seconds after each pulse the color of the recycle stream changed significantly and after five or six pulses the color of the recycle stream appeared to be the same as that at the surface.

Precipitation Results

Before discussing the detailed filtration results it is instrumental to review highlights of some of the precipitation and filtration results for the two mixing environments. The first thirteen columns of Table 2 illustrate the conditions for each test. The target concentrations for the chemical additions were: 1 M OH^- , 0.075 M $\text{Sr}(\text{NO}_3)_2$, and 0.05 M NaMnO_4 . Note, that while the reagent addition rates were the same for both tests, the time-to-add reagents were shorter for the PJM test because the amounts of reagent additions were less. However, the actual method of addition was different. For the well-mixed tank the reagents were simply added to the top of the batch through a one-half-inch line. For the PJM it was required to add the reagents at a velocity of 50 ft/s (15.24 m/s). The hope was that the higher velocity would enhance mixing in the poorly agitated environment, therefore, the reagents were injected through a 0.07-inch (1.78-mm) diameter nozzle.

The next four columns highlight results of the precipitation efficiency for some of key elements from the liquid of the simulant. Those results met RPP-WTP requirements. The last four columns briefly highlight filtration results: the starting and ending concentration of undissolved solids (UDS) during dewatering, the average permeate fluxes at two points during the dewatering, i.e., 5 wt% UDS and 15 wt% UDS, and the final solids concentrations at the end of dewatering.

While Tables 1 and 2 indicate that the two simulants were similar, there were slight differences besides being mixed differently during precipitation. Those other differences include: The two simulants were made at different times, so measurement uncertainty of added ingredients will cause slight variations. The final concentration of precipitation reagents were the same but the method of addition were different and in the case of the PJM, the high velocity jet of the added reagents actually helped to increase bulk mixing. The concentration of precipitated undissolved solids for the PJM test was approximately 25% higher than the well-mixed test, i.e., 1.2 wt% to 1.5 wt% respectively.

The complex mix of species, shown in Table 1, and the resulting make-up of the slurry after precipitation, Table 2, make it very difficult, in not impossible, to say what caused differences in filter performance. The two slurries could have had basically the same percentage of chemical elements or compounds, but the shape, size, or consistency of the undissolved solids could have been slightly different and that slight difference could have been the reason for the difference in permeate flux that will be shown in the next section.

Table 2. Highlights of Precipitation and Filtration Results

(1) Simulant	Entrained Solids (wt%)	Batch size (liters)	Precipitation Temp (°C)	(2) Agitation	19M NaOH or Solid NaOH		1 M Sr(NO ₃) ₂			1M NaMnO ₄			(3) Percent Removed/ DF				Precipitate wt% (5)	(6) Average Filtrate Flux to Reach wt%		Final Conc wt%
					OH ⁻ Addition (M)	Free OH	Wait time (min)	Final Conc. (M)	Time to add (min)	Wait time (min)	Final Conc. (M)	Time to add (min)	Ce	La	Nd	(4) Sr		5 wt%	15 wt%	
AN-102	0.1	880	50	High	0.74	0.96	60	0.075	43.2	30.0	0.05	28.8	80.8	82.8	74.6	99.4	1.2	0.060	0.049	21.7
													5.2	5.8	3.9	128				
AN-102	0.1	572	50	PJM	0.74	1.0	60	0.075	31.2	30.0	0.05	20.6	90.1	95.5	91.7	98.6	1.5	0.021	0.020	18.3
													10	22	12	72				
Notes																				
1. AN-102 simulant was mixed at 6.5 M Na by combining a partial simulant with additional chemicals, aged at least 1 week, then diluted to 6 M Na just prior to using.																				
2. High = 12.8" Lightnin A-310 style impeller in a 42" diameter baffled tank turning at 508 rpm. PJM = pulse jet mixer pulsing 6% of the tank volume with a 1.6 second drive pulse repeated every 77 seconds.																				
3. Percent Removed = [Mass of element A in simulant - Mass of element A in liquid of precipitated mixture (corrected for reagent dilution)] / Mass of element A in Simulant, DF = Mass of element A in simulant / Mass of element A in liquid of precipitated mixture (corrected for reagent dilution).																				
4. The pilot scale work could not actually measure the amount of Sr-90 that would be removed as no radioactive isotopes could be used. The percent of Sr removed and DF shown were based on the recipe amount and assumed 100% isotopic dilution by the nonradioactive Sr added as part of the process. This represents the theoretical maximum that can be obtained.																				
5. The undissolved solids amount increased from the entrained wt% amount in the stimulant feed to the Precipitate wt% after the Sr/TRU reaction and to the Final Conc wt% after concentration in the crossflow filter.																				
6. Units are gpm/ft ² of filter area at an axial velocity of 12 ft/sec and TMP of 40 psi for batches 3 & 4.																				

Comparison of Filtration in the Pilot-Scale Crossflow Ultrafiltration Test Facility

The principal reason for the pilot-scale cross-flow ultrafiltration test was to determine the filterability of different preparations of the organic-based precipitated slurry. However, for both precipitated simulants the filtering process was the same, i.e.,

1. Fill the pilot cross-flow test rig with slurry and take initial slurry and permeate samples.
2. Begin filtering while directing the permeate to a storage location so dewatering could commence.
3. Backpulse the permeate when the permeate flux drop below 0.015 gpm/ft².
4. Continue dewatering until the slurry reached 20 wt% UDS and the dewatering period was at least 12 hours.
5. Stop dewatering and take final slurry samples.

Table 3 shows the highlight results for the two tests as well as the simulant properties.

Table 3. Comparison among the two AN-102 dewatering tests

Batch of AN-102 Simulant>>	Mechanical Agitator	PJM
Date of Test	22-23 Oct. 2002	12-13 Mar. 2002
Duration of Test	12 hours	20 hours
Volume of Slurry Dewatered	880 liters	572 liters
Mixing Conditions	Well Mixed	Not known
Slurry Precipitation Conditions	Table 2	Table 2
Highest Measured Permeate Flux	0.11 gpm/ft ²	0.05 gpm/ft ²
Average Permeate Flux over duration	0.048 gpm/ft ²	0.019 gpm/ft ²
<u>Low Solids Concentrations at the start of dewatering</u>		
Insoluble Solids	1.2 wt%	1.5 wt%
Total Solids	32.7 wt%	33.3 wt%
Slurry Consistency	4.0 cP	4.2 cP
Yield Stress	0 Pa	0 Pa
Permeate Viscosity	3.8 cP	3.7 cP
Slurry Density	1.29 g/ml	1.29 g/ml
Permeate Density	1.279 g/ml	1.277 g/ml
PSD [2] (by volume dist.): Mean	8.6 micron (48%) [1]	
PSD (by volume dist.): Mean	2.3 micron (52%) [1]	2.7 micron
PSD (by volume dist.): Std Dev	4.3 micron	1.9 micron
PSD (by volume dist.): spread	1 to 52 micron	0.8 to 37 micron
PSD (by number dist.): Mean	1.9 micron	1.8 micron
PSD (by number dist.): Std Dev	0.5 micron	0.6 micron
PSD (by number dist.): spread	1 to 19 micron	<0.7 to 16 micron
<u>High Solids Concentration at the end of dewatering</u>		
Insoluble Solids	21.7 wt%	18.3 wt%
Total Solids	47.2 wt%	45.8 wt%
Slurry Viscosity	20 cP	14.8 cP
Yield Stress	8.6 Pa	7.7 Pa
Permeate Viscosity	3.7 cP	3.8 cP
Slurry Density	1.43 g/ml	1.38 g/ml
Permeate Density	1.285 g/ml	1.286 g/ml
PSD (by volume dist.): Mean	8.2 micron (13%) [1]	
PSD (by volume dist.): Mean	0.9 micron (87%) [1]	2.1 micron
PSD (by volume dist.): Std Dev	0.25 micron	0.8 micron
PSD (by volume dist.): spread	<0.7 to 44 micron [3]	0.9 to 16 micron
PSD (by number dist.): Mean	0.8 micron	1.8 micron
PSD (by number dist.): Std Dev	0.1 micron	0.4 micron
PSD (by number dist.): spread	<0.7 to 2 micron [3]	0.9 to 11 micron
Notes: [1] - Bi-modal distribution, [2] - PSD = particle size distribution, [3] - Minimum size measurement for the PSD technique was 0.7 micron. The PSD plots indicated the smallest particles were smaller than 0.7 micron.		

Figure 5 shows the entire filtration test for the well-mixed precipitated slurry. During the test the slurry axial velocity through the filter was maintained constant at 12 ft/s (3.7m/s) and the pressure across the porous-tube membrane (referred to as the transmembrane pressure, or TMP) was maintained constant at 40 psid (276 kPa). The resulting permeate flux stayed above the target mean of 0.02 gpm/ft² (4.9 cm/hr) for the first 11.5 hours of the test. At 11.5 hours the undissolved solids concentration reached 14 wt%. The entire test only lasted just over 12 hours when the undissolved solids concentration went above 20 wt%. The large drop off at the end was after the concentration reached approximately 14 wt% UDS and dewatering continued until it went above the target of 20 wt%. Over the entire 12.2 hours of dewatering, the permeate flux averaged at 0.048 gpm/ft² (11.8 cm/hr).

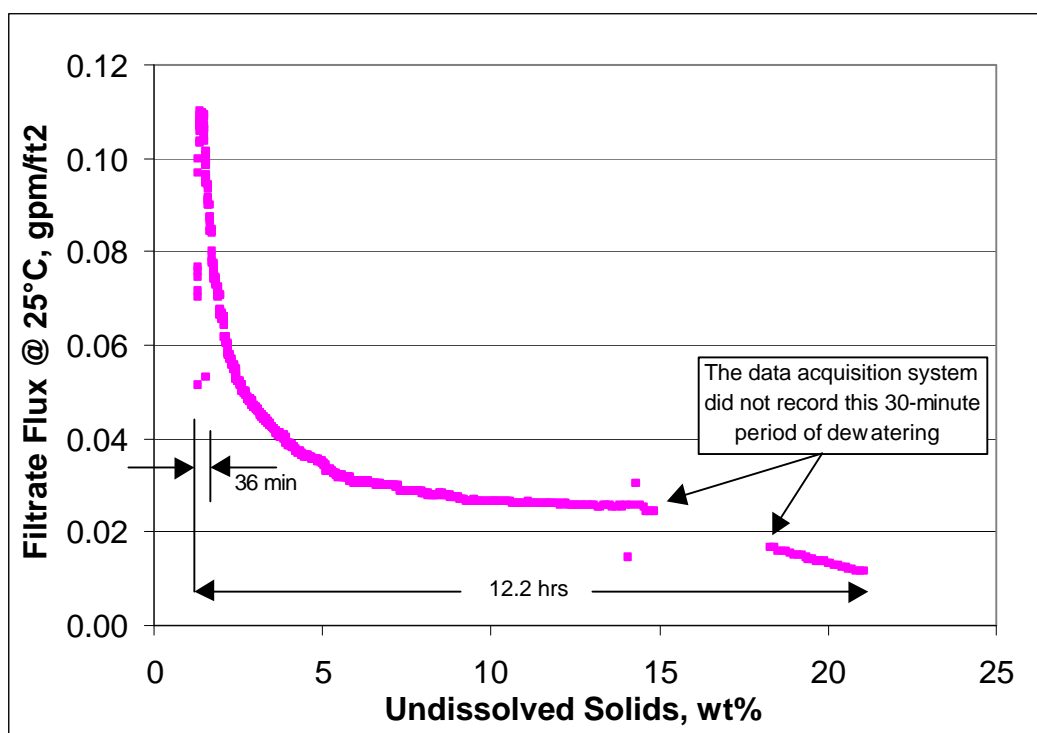


Figure 5. Pilot-scale cross-flow dewatering after well-mixed precipitation

After completing the test with well-mixed precipitation conditions, the cross-flow test rig was cleaned and readied to repeat the process with the more WTP-prototypic mixing conditions using the PJM. Figure 6 shows the entire data set as the undissolved solids concentration increased from 1.5 to 18 wt%, over the 19.5-hour period of dewatering. (The target concentration of 20 wt% UDS could not be reached because of the lack of sufficient simulant.) The average permeate flux over that period was 0.019 gpm/ft² (4.6 cm/hr). That is, the average flux was 40% of that for the well-mixed test.

For the PJM test, RPP-WTP requested the backpulsing criterion be raised from 0.015 gpm/ft² to 0.02 gpm/ft². However, in just over 5 hours permeate flux dropped below this new target. A backpulse was done but within 30 minutes the flux dropped below the criterion again. Subsequent backpulses became even less effective and therefore were discontinued. It appeared that this mixture caked the filter surface in a way that made backpulsing all but useless. Interestingly, after the permeate flux dropped to approximately 0.015 gpm/ft² (3.6 cm/hr) it seem to reach an asymptote, or slightly increased. As before, after reaching 13 to 14 wt% UDS the flux began to drop again.

A conclusion from the PJM test is that if a permeate flux of better than 0.02 gpm/ft² (4.9 cm/hr) is required, then the precipitation mixing environment needs to be better. However, while the pilot test used only one PJM in the precipitation tank, the RPP-WTP plant will have multiple PJM units for its precipitation tank. Creative uses of different mixing cycles for the multiple jet pumps may overcome the poor mixing results of this single PJM test. It is important to note that the overall average flux of 0.019 gpm/ft² (4.7 cm/hr), is within measurement uncertainty (± 0.001 gpm/ft² or ± 0.25 cm/hr) of the 0.020 gpm/ft² (4.9 cm/hr) RPP-WTP target and therefore

is sufficient for plant operation. This means that any better mixing will lead to enhanced plant operation.

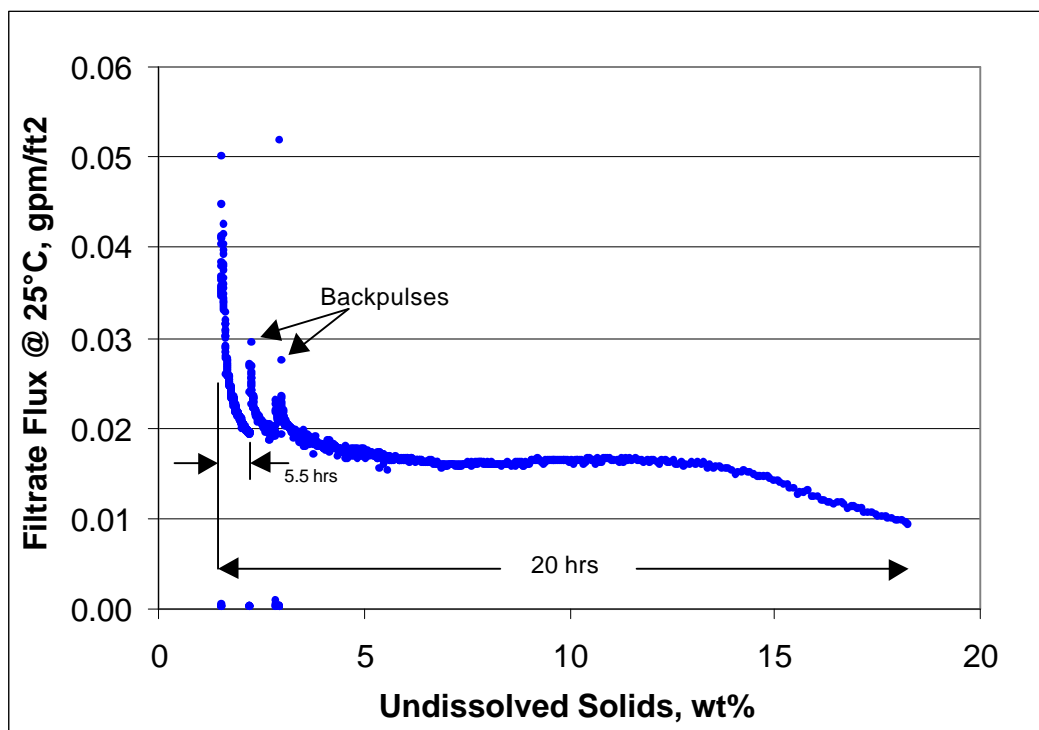


Figure 6. Pilot-scale cross-flow dewatering after PJM precipitation

One notable feature in both Figs. 5 and 6 is the sharp drop in filter flux when the undissolved solids concentration went beyond 14 wt%. Roughly speaking, there appears to be three distinct filtering regions:

From 0 to 5 wt% the filter flux drops precipitously as the filter cake forms and grows fast, relative to its initially formed thickness.

From 5 wt% to 15 wt% the filter flux is relatively stable. The filter cake is formed and further growth is slow, relative to the established thickness.

Greater than 15 wt%, the filter flux begins to drop faster because the solids are close enough together to significantly increase the slurry viscosity, probably exponentially.

Conclusions

1. Filtering to above 15 wt% undissolved solids was attainable, with results in the 18 to 22 wt% range.

2. Backpulsing the filter with this Envelope C-type slurry was not very effective and after reaching an undissolved solids concentration of approximately 5 wt% backpulsing became ineffective.
3. When Sr/TRU precipitation of an Envelope C-type slurry occurs in a well-mixed environment the resulting average filter flux is significantly higher than required by RPP-WTP (0.048 gpm/ft² as compared to 0.02 gpm/ft²).
4. When Sr/TRU precipitation of an Envelope C-type slurry occurs in a PJM environment, with a single jet, the resulting average filter flux is marginal compared to the requirement (0.019 gpm/ft² as compared to 0.02 gpm/ft²).

References

- Duignan, M. R., *Final Report: Pilot-Scale Cross-Flow Ultrafiltration Test Using a Hanford Site Tank 241-AN-102 Waste Simulant*, **USDOE Report WSRC-TR-2003-00204**, Rev. 0, Westinghouse Savannah River Co. (2003).
- Eibling, R. E., *Development of a Supernate Simulant for Hanford Tank 241-AN-102 Waste*, **USDOE Report WSRC-TR-2002-00040**, Rev. 0, Westinghouse Savannah River Co. (2002).
- Williams, M. R., Steeper, T. J., *Pilot Scale Precipitation Tests of Envelope C Simulants*, **USDOE Report WSRC-TR-2003-00064**, Rev. 0, Westinghouse Savannah River Co. (2004)
- Zamecnik, J. R., Baich, M. R., Hansen, E. K., Poirier, M. R., *AN-102 Simulant Sr/TRU Precipitation and Ultrafiltration*, **USDOE Report WSRC-TR-2003-00056**, Rev. 0, Westinghouse Savannah River Co. (2003).
- Zamecnik, J. R., Baich, M. R., Duignan, M. R., Nash, C. A., Poirier, M. R., *Filtration of a Hanford Site Tank 241-AN-102 Waste Sample with Alternate Sr/TRU Precipitation Conditions at Bench and Pilot Scales*, **USDOE Report WSRC-MS-2003-00756**, Rev. 0, Westinghouse Savannah River Co. (2003).